CLAIMS

What is Claimed is:

1. A method of reducing the quantization error in a plurality of beacon beams wherein each beacon beam is digitally formed using a plurality of channels, comprising the steps of:

(a) computing quantized channel weights $\widetilde{W}_c$ from channel weights W_c for at least some of the channels;

(b) estimating the quantization error ΔB_a for each of the beacon beams from a difference between the channel weights W_c and the computed quantized channel weights $\widetilde{W}_c$; and

(c) adding the estimated quantization error ΔB_a to the beacon beams.

2. The method of claim 1, wherein the beacon beam comprises a communication beam.

3. The method of claim 1, wherein steps (a)-(c) are performed in a terrestrial processor.

4. The method of claim 1, wherein steps (a)-(c) are performed in a satellite processor.

5. The method of claim 1, further comprising the step of: computing an azimuth bias angle az_{bias} and an elevation bias angle el_{bias} from the plurality of quantized beacon beams.

6. The method of claim 5, wherein the azimuth bias angle and elevation bias angle are computed according to $az_{bias} \approx K_{az} \frac{2\left(\tilde{E} \quad \Delta E\right) - 2\left(\tilde{W} \quad \Delta W\right)}{\left(\tilde{E}\right)^2 + \left(\tilde{W}\right)^2}$,

$$el_{bias} \approx K_{el} \frac{2\left(\tilde{N} \quad \Delta N\right) - 2\left(\tilde{S} \quad \Delta S\right)}{\left(\tilde{N}\right)^2 + \left(\tilde{S}\right)^2}$$

wherein, $\tilde{N}$, $\tilde{S}$, $\tilde{E}$, $\tilde{W}$ are predicted beam magnitudes for a North, South, East, and West beacon beams, respectively, and ΔN, ΔS, ΔE, ΔW are estimated quantization errors ΔB_a for the North, South, East, and West beacon beams, respectively.

7. The method of claim 5, wherein the azimuth and elevation bias angles az_{bias} and el_{bias} are used to correct beacon measured angles for compensating the estimated quantization errors ΔB_a.

8. The method of claim 1, wherein the step of adding the estimated quantization error ΔB_a to each of the beacon beams comprises the steps of:

estimating a channel response X_a for at least some of the channels; and

computing the quantization error ΔB_a from the channel response.

9. The method of claim 8, wherein the quantization error ΔB_a is computed from the channel response according to $\Delta B_a \approx \left(W_c - \tilde{W}_c\right)^T X_a$.

10. The method of claim 8, wherein the channel response X_a is estimated according to $X_a = X_0(az, el)\big|_{t_c} k_c\big|_{t_c}$, wherein $X_0(az, el)\big|_{t_c}$ is a nominal response of each channel at a calibration time t_c and $k_c\big|_{t_c}$ is a thermal gain factor k_c evaluated at a calibration time t_c.

11. The method of claim 10, further comprising the step of computing the thermal gain factor k_c.

12. The method of claim 11, wherein the step of computing the thermal gain factor k_c comprises the steps of:

computing $k_c = Diag(X_0(az_c, el_c))^{-1} X_c(az_c, el_c, k_c)$, wherein $(X_0(az_c, el_c))$ is the nominal value of the channel to a calibration probe placed at a location (az_c, el_c) and $X_c(az_c, el_c, k_c)$ is the response of each channel to a calibration probe placed at the location (az_c, el_c).

13. The method of claim 1, further comprising the step of computing the channel weights W_c according to:

$W_c = Diag(X_c(az, el, k_c))^{-1} Diag(X_0(az, el))\, W = Diag(K_c)^{-1} W$, wherein W represents nominal channel weights.

14. An apparatus for reducing the quantization error in a plurality of beacon beams wherein each beacon beam is digitally formed using a plurality of channels, comprising:

means for computing quantized channel weights $\widetilde{W}_c$ from channel weights W_c for at least some of the channels;

means for estimating the quantization error ΔB_a for each of the beacon beams from a difference between the channel weights W_c and the computed quantized channel weights $\widetilde{W}_c$; and

means for adding the estimated quantization error ΔB_a to the beacon beams.

15. The apparatus of claim 14, wherein the beacon beam comprises a communication beam.

16. The apparatus of claim 14, wherein the means for computing quantized channel weights $\widetilde{W}_c$ from channel weights W_c for at least some of the channels, means for estimating the quantization error ΔB_a for each of the beacon beams from a difference between the channel weights W_c and the computed quantized channel weights $\widetilde{W}_c$; and means for adding the estimated quantization error ΔB_a to the beacon beams comprises a terrestrial processor.

17. The apparatus of claim 14, wherein the means for computing quantized channel weights $\widetilde{W}_c$ from channel weights W_c for at least some of the channels, means for estimating the quantization error ΔB_a for each of the beacon beams from a difference between the channel weights W_c and the computed quantized channel weights $\widetilde{W}_c$; and means for adding the estimated quantization error ΔB_a to the beacon beams comprises a satellite processor.

18. The apparatus of claim 14, further comprising:

means for computing an azimuth bias angle az_{bias} and an elevation bias angle el_{bias} from the plurality of quantized beacon beams.

19. The apparatus of claim 18, wherein the azimuth bias angle and elevation bias angle are computed according to $az_{bias} \approx K_{az} \frac{2(\tilde{E} \quad \Delta E) - 2(\tilde{W} \quad \Delta W)}{(\tilde{E})^2 + (\tilde{W})^2}$,

$$el_{bias} \approx K_{el} \frac{2(\tilde{N} \quad \Delta N) - 2(\tilde{S} \quad \Delta S)}{(\tilde{N})^2 + (\tilde{S})^2}$$

wherein, $\tilde{N}$, $\tilde{S}$, $\tilde{E}$, $\tilde{W}$ are predicted beam magnitudes for a North, South, East, and West beacon beams, respectively, and ΔN, ΔS, ΔE, ΔW are estimated quantization errors ΔB_a for the North, South, East, and West beacon beams, respectively.

20. The apparatus of claim 18, wherein the azimuth and elevation bias angles az_{bias} and el_{bias} are used to correct beacon measured angles for compensating the estimated quantization errors ΔB_a.

21. The apparatus of claim 14, wherein the means for adding the estimated quantization error ΔB_a to each of the beacon beams comprises:

means for estimating a channel response X_a for at least some of the channels; and

means for computing the quantization error ΔB_a from the channel response.

22. The apparatus of claim 21, wherein the quantization error ΔB_a is computed from the channel response according to $\Delta B_a \approx (W_c - \tilde{W}_c)^T X_a$.

23. The apparatus of claim 21, wherein the channel response X_a is estimated according to $X_a = X_0(az,el)\big|_{t_c} k_c\big|_{t_c}$, wherein $X_0(az,el)\big|_{t_c}$ is a nominal response of each channel at a calibration time t_c and $k_c\big|_{t_c}$ is a thermal gain factor k_c evaluated at a calibration time t_c.

24. The apparatus of claim 23, further comprising means for computing the thermal gain factor k_c.

25. The apparatus of claim 24, wherein the means for computing the thermal gain factor k_c comprises:

means for computing $k_c = Diag(X_0(az_c,el_c))^{-1} X_c(az_c,el_c,k_c)$, wherein $(X_0(az_c,el_c))$ is the nominal value of the channel to a calibration probe placed at a location (az_c,el_c) and $X_c(az_c,el_c,k_c)$ is the response of each channel to a calibration probe placed at the location (az_c,el_c).

26. The apparatus of claim 25, further comprising means for computing the channel weights W_c according to:

$W_c = Diag(X_c(az,el,k_c))^{-1} Diag(X_0(az,el))\, W = Diag(K_c)^{-1} W$, wherein W represents nominal channel weights.

27. A method for reducing the asymmetry error in a beacon, wherein the beacon comprises of multiple beams, and each beam is formed from a multiplicity of feed channels, comprising the step of:

(a) computing asymmetry angles; and

(b) using the asymmetry angles to correct the beacon sensor measurements.

28. The method of claim 27, wherein the step of using the asymmetry angles to correct the beacon sensor measurements includes the step of using the asymmetry angles as beacon bias angles.

29. The method of claim 27, wherein the step of using the asymmetry angles to correct the beacon sensor measurements includes the step of using the asymmetry angles as time-varying beacon bias angles.

30. The method of claim 27, wherein steps (a)-(b) are performed in a terrestrially-based processor.

31. The method of claim 27, wherein steps (a)-(b) are performed by a satellite processor.

32. The method of claim 29, wherein the step of computing the asymmetry angles comprises the step of:

computing a difference between known azimuth/elevation angles, (az el), and their corresponding predicted beam-formed azimuth/elevation angles, (az_c el_c):(az-az_c el-el_c).

33. The method of claim 32, wherein the corresponding beam-formed azimuth/elevation angles are computed according to $az_c = K_{az} \frac{E^2 - W^2}{E^2 + W^2}$, and $el_c = K_{el} \frac{N^2 - S^2}{N^2 + S^2}$ where K_{az} and K_{el} are optimal beacon slopes, and E, W, N, and S are East, West, North, and South beam magnitudes of the beacon beams.

34. The method of claim 33, wherein the E, W, N, and S beam magnitudes of the beacon are computed according to:

$E(az, el) = W_E{}^T X$;

$W(az, el) = W_W{}^T X$;

$N(az, el) = W_N{}^T X$;

$S(az, el) = W_S{}^T X$; and

wherein the W_E, W_W, W_N, and W_S are the channel weights of East, West, North, and South beacon beams, and X is a response of a plurality of feed chains at look angle (az el).

35. An apparatus for reducing the asymmetry error in a beacon, wherein the beacon comprises of multiple beams, and each beam is formed from a multiplicity of feed channels, comprising the step of:

means for computing asymmetry angles; and

means for using the asymmetry angles to correct the beacon sensor measurements.

36. The apparatus of claim 35, wherein the means for using the asymmetry angles to correct the beacon sensor measurements includes means for using the asymmetry angles as beacon bias angles.

37. The apparatus of claim 35, wherein the means for using the asymmetry angles to correct the beacon sensor measurements includes means for using the asymmetry angles as time-varying beacon bias angles.

38. The apparatus of claim 35, wherein the means for computing asymmetry angles and the means for using the asymmetry angles to correct the beacon sensor measurements comprise a terrestrially-based processor.

39. The apparatus of claim 35, wherein the means for computing asymmetry angles and the means for using the asymmetry angles to correct the beacon sensor measurements comprise a satellite-based processor.

40. The apparatus of claim 35, wherein the means for computing the asymmetry angles comprises:

means for computing a difference between known azimuth/elevation angles, (az el), and their corresponding predicted beam-formed azimuth/elevation angles, (az_c el_c):($az-az_c$ $el-el_c$).

41. The apparatus of claim 40, wherein the corresponding beam-formed azimuth/elevation angles are computed according to $az_c = K_{az}\frac{E^2 - W^2}{E^2 + W^2}$, and $el_c = K_{el}\frac{N^2 - S^2}{N^2 + S^2}$ where K_{az} and K_{el} are optimal beacon slopes, and E, W, N, and S are East, West, North, and South beam magnitudes of the beacon beams.

42. The apparatus of claim 41, wherein the E, W, N, and S beam magnitudes of the beacon are computed according to:

$E(az,el) = W_E^T X$;

$W(az,el) = W_W^T X$;

$N(az,el) = W_N^T X$;

$S(az,el) = W_S^T X$; and

wherein the W_E, W_W, W_N, and W_S are the channel weights of East, West, North, and South beacon beams, and X is a response of a plurality of feed chains at look angle (az el).